Fluvial Sediment in the Little Arkansas River Basin Kansas

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1798-B

Prepared in cooperation with the City of Wichita and the Kansas Water Resources Board

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By C. D. ALBERT and G. J. STRAMEL

SEDIMENTATION IN SMALL DRAINAGE BASINS

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[Plates are in pocket]

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GLOSSARY

Concentration-duration curve. A cumulative-frequency curve that shows the percentage of time that specified daily mean concentrations are equaled or exceeded.

Drainage density. The ratio of the total length of all channels in a basin to the drainage area of the basin.

Elongation ratio. The ratio of the diameter of a circle having the same area as the basin to the maximum length of the basin parallel to the principal drainage line.

Fluvial sediment. Material that originates mostly from the disintegration of rocks and that is transported by, suspended in, or deposited from water; this sediment includes the chemical and biochemical precipitates and the organic material, such as humus, which has reached such an advanced stage of disintegration and decomposition that the original structure and characteristics of the living organic unit are not recognizable.

Particle-size classification. Diameters are as follows: Gravel, 2–64 mm; sand, 0.062–2 mm; silt, 0.004–0.062 mm; clay, less than 0.004 mm.

Relief ratio. The ratio of the maximum relief in a basin to the longest dimension of the basin parallel to the principal drainage line.

Suspended sediment. Fluvial sediment that at any given time is maintained in suspension by the upward components of turbulent currents or by colloidal suspension.

Suspended-sediment concentration. The ratio of the weight of sediment to the weight of water-sediment mixture expressed in parts per million. A part per million is a unit weight of sediment in a million unit weights of water-sediment mixture.

Suspended-sediment discharge or load. A rate of sediment movement computed as the product of the suspended-sediment concentration, the water discharge, and a constant for converting the units to a weight per unit time, generally tons per day.

Total sediment discharge or load. The weight of all the sediment passing a section in a unit time.

FLUVIAL SEDIMENT IN THE LITTLE ARKANSAS RIVER BASIN, KANSAS

By C. D. Albert and G. J. Stramel [1]

ABSTRACT

Characteristics and transport of sediment in the Little Arkansas River basin in south-central Kansas were studied to determine if the water from the river could be used as a supplemental source for municipal supply or would provide adequate recharge to aquifers that are sources of municipal and agricultural water supplies. During periods when overland flow contributed a significant amount to streamflow, the suspended sediment in the Little Arkansas River at Valley Center averaged about 85 percent of clay, about 13 percent of silt, and about 2 percent of sand. The average annual suspended-sediment discharge for the water years 1958, 1959, 1960, and 1961 was about 306,000 tons, and about 80 percent of the load was transported during 133 days of the 1,461-day period. The average daily water discharge of 352 cubic feet per second for the period 1958–61 was more than the long-term (39-year) average of 245 cfs; therefore, the average annual sediment load for 1958–61 was probably greater than the average annual load for the same long-term period.

Studies of seepage in a part of the channel of Kisiwa Creek indicated that an upstream gravel-pit operation yielded clays which, when deposited in the channel, reduced seepage. A change in plant operation and subsequent runoff that removed the deposited clays restored natural seepage conditions.

Experiments by the Wichita Water Department showed that artificial recharge probably cannot be accomplished by using raw turbid water that is injected into wells or by using pits. Recharge by raw turbid water on large permeable areas or by seepage canals may be feasible.

Studies of chemical quality of surface water at several sites in the Little Arkansas River basin indicate that Turkey Creek is a major contributor of chloride and other dissolved solids to the Little Arkansas River and that the dissolved-solids content is probably highest during low-flow periods when suspended-sediment concentration is low. Data collected by the Wichita Water Department indicate that chloride concentrations are diminishing with time at sampled locations.

INTRODUCTION

Planning for the systematic and economical development of water resources requires knowledge and appraisal of the characteristics and

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transport of fluvial sediment. Information on fluvial sediment may be applied in designing and operating storage reservoirs, designing diversion structures, predicting potential water-treatment problems, and determining the suitability of surface-water supplies for artificial recharge of ground-water reservoirs. Water-discharge records collected by the Geological Survey at Valley Center since 1922 indicate that the water yield from the Little Arkansas River basin is adequate for municipal use and for recharge of aquifers.

The U. S. Geological Survey, in cooperation with the Wichita Water Department and the Kansas Water Resources Board, investigated fluvial-sediment characteristics in the Little Arkansas River basin during the period July 1957 to September 1961. The investigations were designed to provide data on daily and annual suspended-sediment discharge, concentration, and particle-size distribution for Little Arkansas River at Valley Center; periodic data on instantaneous sediment discharge and particle-size distribution for other selected main-stem sites; and reconnaissance data on sediment discharge and particle-size distribution for selected tributary streams throughout the basin. Short-term special investigations were also made of the chemical quality of water.

Previous sediment data were collected by the U.S. Army, Corps of Engineers, Tulsa District, and were restricted to periodic determinations of suspended-sediment discharge at Little Arkansas River at Valley Center. Information has been obtained weekly on chemical quality of water in the basin since 1952, and aspects of ground-water recharge have been investigated by the Wichita Water Department.

The fluvial-sediment investigations by the Geological Survey were under the general supervision of D. M. Culbertson, district engineer. R. H. Hess, director of water and sewage treatment, Wichita, and Robert L. Smith, executive secretary of the Kansas Water Resources Board, assisted in planning the investigations.

DESCRIPTION OF THE BASIN

The Little Arkansas River basin, which includes parts of seven counties in south-central Kansas, has a total area of 1,343 square miles, of which about 77 square miles does not contribute directly to surface runoff. (See pl. 1.) The total population directly dependent on the water resources of the Little Arkansas River basin for municipal and domestic supplies is about one-half million.

The economy of the basin is based mainly on diversified agriculture. In 1959, 3 of the counties in the basin were among the top 10 wheat-producing counties in the State; 4, among the top 10 sorghum-grain producers; 2, among the top 10 oat producers; 3, among the top 10 alfalfa producers; and 2, among the top 10 counties in number of cattle on farms and in milk production on farms. About 22,000 acres in McPherson and Harvey Counties and in a small part of Sedgwick County is irrigated, about 85-percent of the need being supplied by ground water. The potential supply for irrigation is much greater than the present development.

In addition, the economy is supported significantly by the petroleum industry in parts of the basin, by diversified industrial development in Wichita, by light industry in McPherson and Newton, and by local mining of sand and gravel for construction purposes.

GEOLOGY

The land surface supplying sediment to the Little Arkansas River consists of consolidated rocks of Permian and Cretaceous age and of large unconsolidated deposits of Quaternary age. (See pl. 2.) The consolidated rocks are nearly horizontal strata formed in a marine—shallow water or onshore—environment. Although the Permian rocks include some beds of evaporites, they are composed mostly of shale and limestone; the Cretaceous rocks, on the other hand, are composed almost wholly of sandstone, siltstone, and shale. Laid down by streams or the wind in a continental environment, the Quaternary deposits consist of gravel, sand, silt, and clay.

The consolidated rocks constitute not only a part of the land surface in the basin but also the bedrock beneath the unconsolidated deposits that compose the remainder of the land surface. The surface of the buried consolidated rocks was shaped by subaerial erosion prior to deposition of the unconsolidated deposits; it differs from the present-day land surface by having greater topographic relief and an arrangement of hills and valleys generally unrelated to those of today.

East of R. 5 W. and in part of Rs. 5 and 6 W., the bedrock surface is composed of strata of the Lower Permian Series—the Sumner Group below and the Nippewalla Group above. In the eastern part of the drainage basin only the Sumner Group remains, but throughout the remainder of the area of Permian rocks, the Summer Group constitutes the floor and lower sides of the buried valleys and the Nippewalla Group constitutes the upper sides of the buried valleys and the intervening hills. The Sumner Group crops out in the present-day terrain only in Tps. 23–25 S., R. 1 E., and the Nippewalla Group crops out in Tps. 19–22 S., Rs. 3–6 W. The Permian strata are composed of calcium and magnesium carbonates (limestone and dolomite), calcareous fine-grained clastics (shale), and anhydrite, gypsum, and halite (evaporites).

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In a small part of R. 5 W., most of R. 6 W., and all of Rs. 7 and 8 W., the bedrock surface is composed of strata of the Lower Cretaceous Series—the Kiowa Shale below and the Dakota Sandstone above. About half the Cretaceous bedrock surface is exposed in the present-day terrain, and the remainder is mantled by unconsolidated Quaternary deposits. The Cretaceous rocks consist largely of clastics but include a few thin layers of limestone. The clastics are mostly fine grained—clay, shale, and siltstone—but in the Dakota some are fine- to medium-grained channel-fill sandstones. Ironstone nodules and iron-cemented beds are common in the Dakota Sandstone.

The Quaternary deposits of fluvial origin were derived from source areas to the west and northwest. Although the Little Arkansas River, together with its tributaries, is the only agent of fluvial-sediment transport and deposition in the basin today, it has transported and deposited only a small fraction of the great mass of fluvial deposits within its drainage basin. Instead, the available evidence indicates that the ancestral Smoky Hill and Arkansas Rivers were the principal transporting and depositing agents. During part of Quaternary time the Smoky River was probably a tributary of the Arkansas River, and the flows of these streams as well as the sediment they deposited merged in the southeastern part of the area now drained by the Little Arkansas River. The fluvial deposits are characterized by intercalated channel fills of different texture. Most of the grains and pebbles are composed of quartz, but some are composed of feldspar and various igneous rocks.

For the most part the fluvial deposits are buried beneath a mantle of wind-deposited sand and silt. A large area of sand dunes borders the southwest side of the Little Arkansas River from T. 23 S., R. 2 W., to T. 20 S., R. 6 W., and there are a few smaller areas of sand dunes in Tps. 23 and 24 S., Rs. 1–4 W. Because dune sand is so porous, the sand-dune areas yield little or no overland runoff; instead, precipitation that escapes evaporation is absorbed by the sand and, on infiltrating to the zone of saturation, percolates toward the river. The area of wind-deposited silt and sandy silt is much more extensive than the area of dune sand. As silt is fine textured, it is less permeable than sand and, during periods of abundant moisture, generally yields much more direct runoff than it retains as soil moisture or transmits downward to the zone of saturation.

GEOMORPHOLOGY

The lower basin lies partly in the Great Bend Lowland and partly in the McPherson Lowland of the Central Lowland province (Schoewe, 1949) and is typified by low topographic relief and by sand dunes that lie between the Little Arkansas and Arkansas Rivers in Reno and

Harvey Counties. The lower two-thirds of the basin is a plain that has well-defined tributaries and several surface depressions which serve as catchment basins for rainfall and runoff from the immediate area. These depressions, probably caused by solution of subterranean salt deposits and subsidence of the overlying material, may contain water, but a few have been artificially drained.

The upper part of the basin is in the Smoky Hills, a part of the Dissected High Plains section of the Great Plains province. Drainage is well defined and is incised in outcrops of consolidated rock strata.

Stream systems may be studied from many aspects, such as genetic type, stream pattern, or stages in life history. Factors of a stream system that most affect runoff and erosion are probably stream pattern. drainage density, elongation ratio, and relief ratio.

The principal dendritic drainage channels in the basin are the main stem and 10 major tributaries. Only two of the tributaries, Sand Creek (Rice County) and Kisiwa Creek, drain the area between the Arkansas and Little Arkansas Rivers. Computed or measured geomorphic parameters for the basin are shown in table 1. Drainage density is much lower for the Little Arkansas River basin than for most other parts of Kansas. Although this lower density is not necessarily an indication of poor drainage, the very low densities for Sand Creek (Rice County) basin, Kisiwa Creek basin, and other basins show that stream channels are poorly developed in these basins. The ratio of miles of all tributary channels in a subbasin to miles of main tributary channel in the subbasin differs from one basin to another; in Sand Creek (Rice County) basin, only about two-thirds of a mile of defined tributary channel exists for each mile of main channel, whereas in Blaze Fork, Turkey, and Sand Creek (Harvey County) basins, about 8–9 miles of tributary channel exists for each mile of main channel. The long profiles of the tributaries (fig. 1) also differ considerably. Elongation ratio does not correlate with relief ratio, and neither ratios correlates with drainage density or other subbasin geomorphic parameters.

SOILS

Soil characteristics result from the effects of climate and biological activity on parent material under varying conditions of slope or relief over a period of time. Characteristics of the soil that are especially important in evaluating or interpreting sediment data are the texture and mineralogy, infiltration capacity, permeability, slope, and erodibility. The available information on these characteristics of soils in the Little Arkansas River basin is very generalized and thus is inadequate for predicting sediment yields from specific parts of the basin.

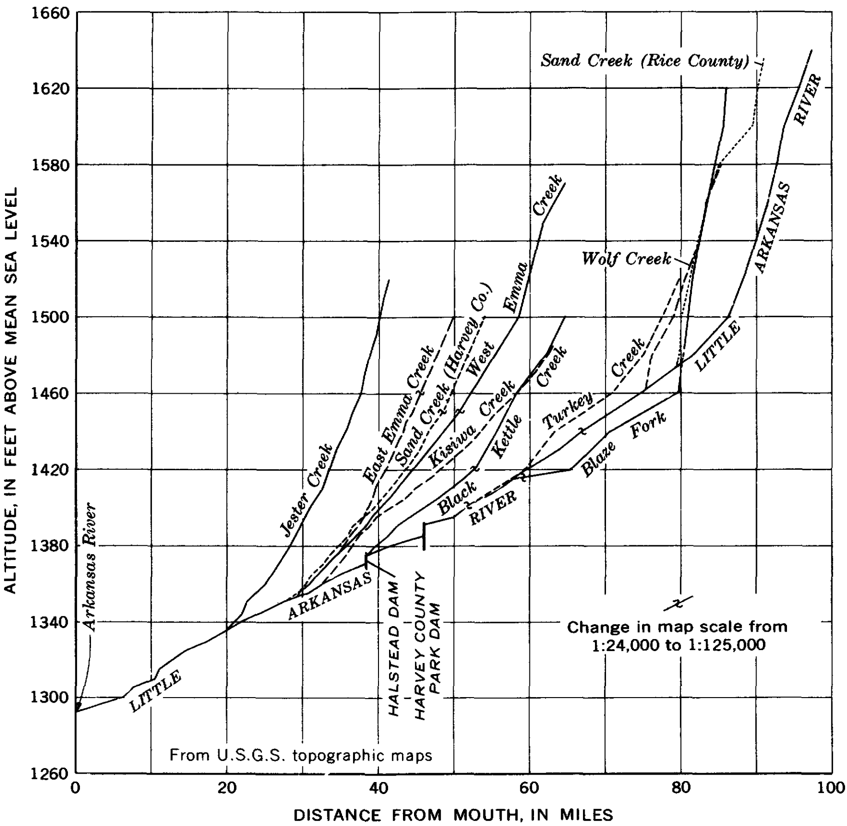

FIGURE 1.—Longitudinal profiles of Little Arkansas River and some major tributaries.

TABLE 1.—*Stream and subbasin parameters of the Little Arkansas River basin*

	Drainage area (sq mi)	Main channel length (miles)	Length of all channels (miles)	Main channel slope (feet per foot)	Drainage density (mile per sq mi)	Relief ratio	Elongation ratio
Sand Creek (Rice County)	29	12	22	0.0024	0.76	0.0033	0.52
Wolf Creek	31	9.8	50	.0022	1.61	.0022	.64
Blaze Fork Creek	166	28.4	241	.0013	1.45	.0017	.54
Turkey Creek	202	28	292	.0008	1.45	.0010	.57
Crooked Creek	45	22	69	.0009	1.53	.0010	.30
Black Kettle Creek	42	26	89	.0009	2.12	.0012	.34
Kisiwa Creek	91	30.6	94	.0008	1.03	.0014	.54
Emma Creek	183	35.2	210	.0012	1.15	.0013	.48
Sand Creek (Harvey County)	95	26.6	194	.0012	2.04	.0013	.52
Jester Creek	56	21.3	116	.0016	2.07	.0021	.47
Little Arkansas River at Valley Center	1,327	80	1,657	.0007	1.25	.0009	.51
Little Arkansas River basin	1,343	96	1,676	.0007	1.25	.0009	.43

The surface horizons of the somewhat immature soils in the upper part of the basin in northeastern Rice County have textures ranging from clay and silty clay to sandy silt; gullies and moderate to severe erosion are common. In parts of Rice, Reno, and McPherson Counties, areas of active sand dunes are interspersed with areas of clay soils having moderate to slow permeability.

The northern and central parts of the basin in McPherson and Harvey Counties have soils developed from loess and alluvial deposits; they have been termed the Claypan Section of the Loess-Outwash Tablelands area in Kansas (U.S. Soil Conserv. Service and Kans. Agr. Expt. Sta., 1947, p. 1–2). Soils in this section have surface textures ranging from clay to silty sand; erosion either from sheetwash or from wind action may be severe.

In the lower part of the basin in Harvey and Sedgwick Counties and upstream along major tributaries, soils have developed from alluvium of Recent age. These soils have surface textures ranging from clay to fine sand, and they are deep, friable, and very fertile. Little or no surface runoff occurs during most rainfall.

LAND USE AND VEGETATION

Vegetation and land use affect soil erosion in many ways. Grass cover and dense root systems reduce sheetwash, increase infiltration capacity, and aid in soil development. Tilled lands are usually unprotected by vegetal cover during an appreciable period each year. Rainfall during such periods may produce gullies in areas of sufficient slope.

Native grasses cover most of the slopes in the upper basin, and tilled crops are grown in small valleys and on alluvial fans. The sandhill or very sandy soil areas of the basin support native grass except for small tilled plots or for areas of active dunes. Diversified farming predominates in the rest of the basin. Intensive farming practices such as contour tillage, terracing, and crop rotation are necessary in parts of the basin as an erosion-control measure; such practices also aid in moisture conservation and replenishment of ground-water reserves.

CLIMATE

The Little Arkansas River basin is in the path of warm, moist air masses that move northward from the Gulf of Mexico and of cold, dry air masses that move southward from the continental interior. As a result, the weather is subject to sudden temperature changes, thunderstorms, and snowstorms. Summers generally are warm and winters are mild. Records of the U.S. Weather Bureau for Hutchinson, McPherson, and Newton are regarded as representative of the basin and were used as the basis for computations of climatological data presented in this report.

The mean annual precipitation, based on about 70 years of record, is 29.8 inches. Most of the precipitation occurs during spring and summer. (See fig. 2.) The maximum annual precipitation, 49.12 inches, was in 1951 at McPherson, and the minimum, 15.24 inches, was in 1956, also at McPherson; the mean annual precipitation at McPherson is 29.34 inches.

During the period of sediment investigations in the basin (1958–61), the mean annual precipitation was 34.7 inches, and three monthly precipitation maximums were established. Precipitation at Hutchinson was 14.69 inches in July 1958; the long-term monthly mean for July is 3.56 inches. Precipitation, mostly snow, at Newton was 2.82 inches in February 1960; the long-term monthly mean is 1.12 inches. Precipitation at Newton was 12.37 inches in August 1960; the long-term monthly mean is 3.45 inches.

The average temperature in the basin is about 56°F, but the annual temperature range is wide. The maximum recorded temperature was 117°F, and the minimum was −28°F.

RUNOFF

Streamflow characteristics and hydraulic conditions affect the total sediment discharge of a stream. Some important factors that affect transport of sediments are the nature of the flow (perennial or ephemeral), frequency and magnitude of floods, percentage of discharge that is contributed by surface runoff, structural controls and reservoirs, stream gradient, and interrelations of stream width, depth, velocity, and discharge.

Data on water discharge have been collected by the U.S. Geological Survey on the Little Arkansas River at Valley Center since June 1922. A recording gage was installed at the river bridge half a mile west of Valley Center in February 1935 and has supplied a continuous record of stream stage, except during the period July 1951–February 1952. The Little Arkansas River floodway was completed in May 1957, and since then part of the high-water flow has been diverted through the floodway upstream from the river gage. Streamflow records for both the river channel and the floodway are published in the series of U.S. Geological Survey water-supply papers entitled "Surface Water Supply of the United States, Part 7." During the period 1922–61, the maximum water discharge was 32,000 cubic feet per second in April 1945, the minimum was 1.0 cfs in October 1956, and the daily mean was 245 cfs. During the period of sediment investigations (1958–61), the

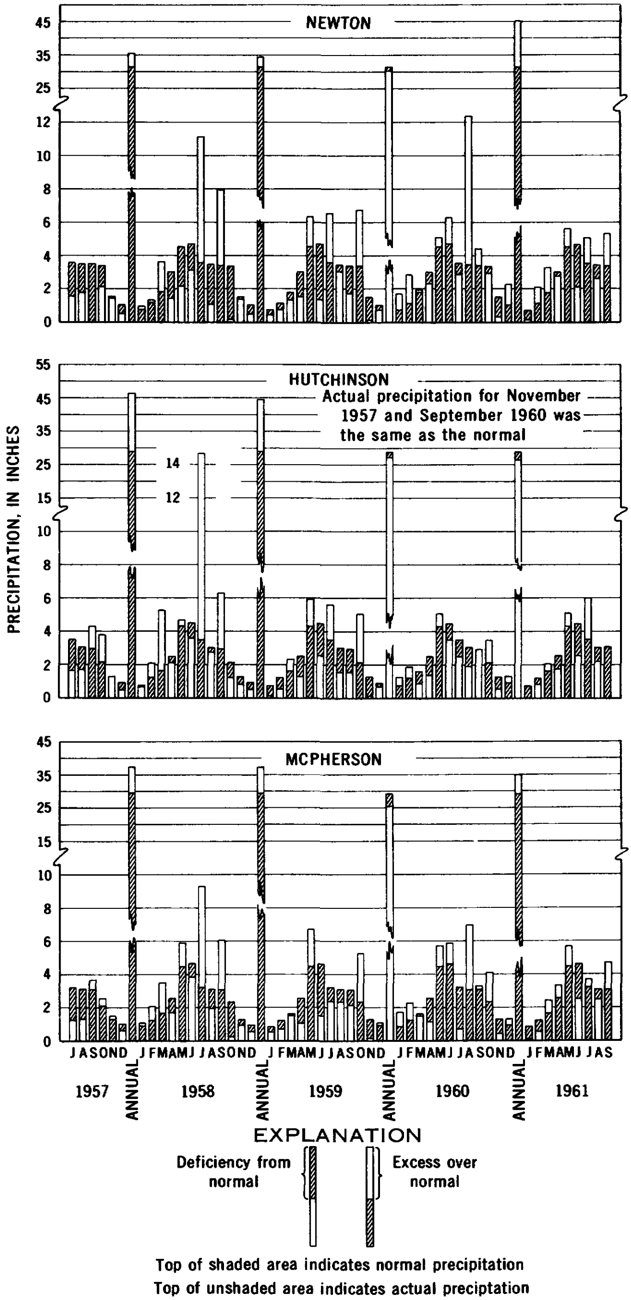

FIGURE 2.—Monthly and annual precipitation for 1957–61 and long-term normal monthly and annual precipitation.

maximum dicharge was 12,800 cfs in May 1961, the minimum was 8.0 cfs in January 1961, and the daily mean was 352 cfs.

Information on flow duration, low-flow frequency, and flood frequency (Furness, 1959, 1960; Ellis and Edelen, 1960) is available for many streams in Kansas. Ellis and Edelen showed that a flood of 10,000 cfs or more at peak stage occurred only 17 times in 7 years during the 34-year period of record. Discharges of 10,000 cfs or more occurred only about 0.1 percent of the time during the period of record (Furness, 1959). A flow-duration curve for the Little Arkansas River can be used to evaluate the potential water supply (fig. 3).

The relations of mean velocity, width, and mean depth to water discharge for the Little Arkansas River at Valley Center are shown in figure 4. The discharge-width relation curve, which flattens above 400 cfs, defines stream-width control by bridge abutments. An abrupt decrease in mean velocity and an increase in depth at about 400 cfs indicate a backwater effect created by downstream controls. The decrease in mean velocity, which is less pronounced after excluding no-flow sections from computations, is caused by downstream riffle control and channel constriction.

During the 1960 water year, low-flow studies were made of water-discharge changes in a downstream direction on the Little Arkansas River. On four occasions, discharge measurements were made along the main stem and on the tributaries. The results indicate that the flow of the Little Arkansas River was effluent during the studies. (See fig. 5.) The results, however, do not preclude the possibility of influent flow in some reaches of the stream and the possibility of ground-water recharge in local areas adjacent to the stream. For the four periods of measurement, the minimum measured discharge at Little Arkansas River at Valley Center was 47 cfs and the maximum measured discharge was 79 cfs. At stream stages significantly higher or lower than those during the study periods, the effluent or influent characteristics of the stream may differ markedly from those of the study period.

Some hydraulic structures and reservoirs are in the Little Arkansas River basin; however, their effect on streamflow and sediment discharge has not been determined. Two small low-head dams are on the Little Arkansas River upstream from Valley Center: one is at Halstead and maintains a conservation pool about three-fourths of a mile long, and the other is at the Harvey County Park about 5 miles upstream from Halstead.

Many small reservoirs for agricultural uses have been built in the basin. In Rice, McPherson, and Harvey Counties, the U.S. Conservation Service reported 421 of these reservoirs with an aggregate

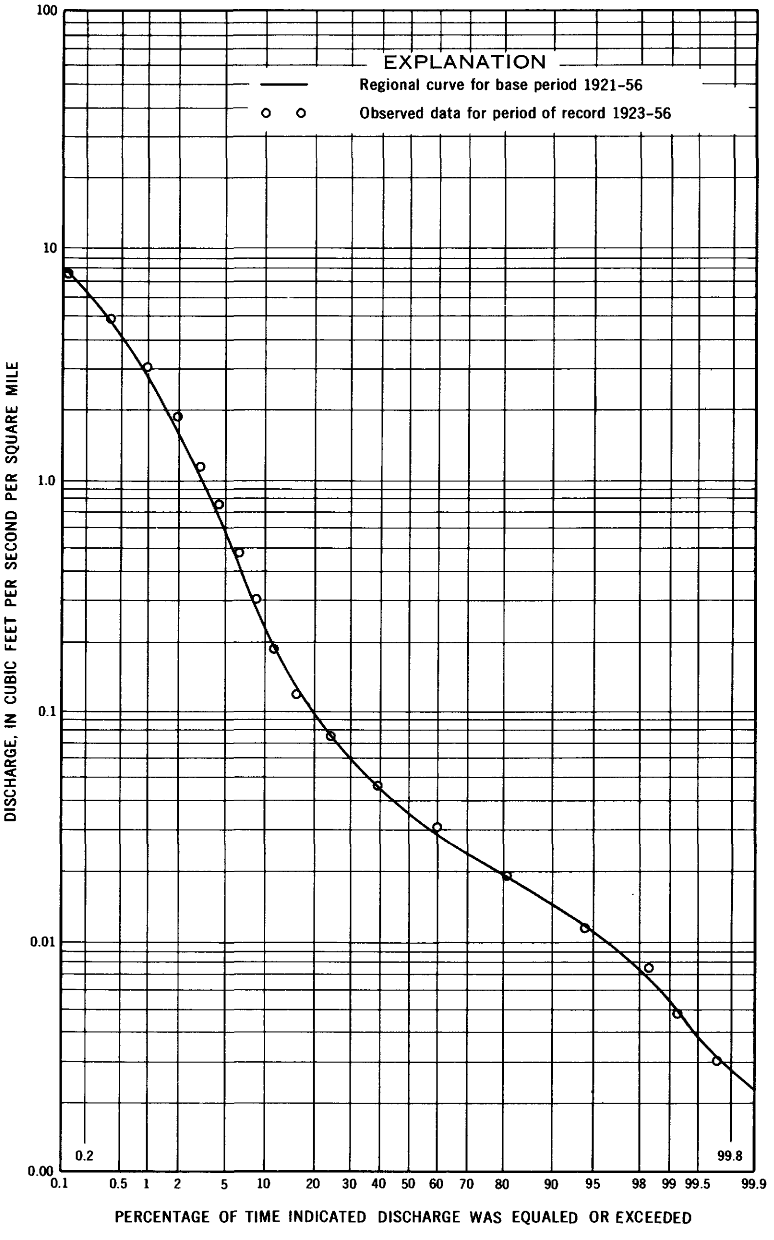

FIGURE 3.—Flow-duration curve, Little Arkansas River at Valley Center.

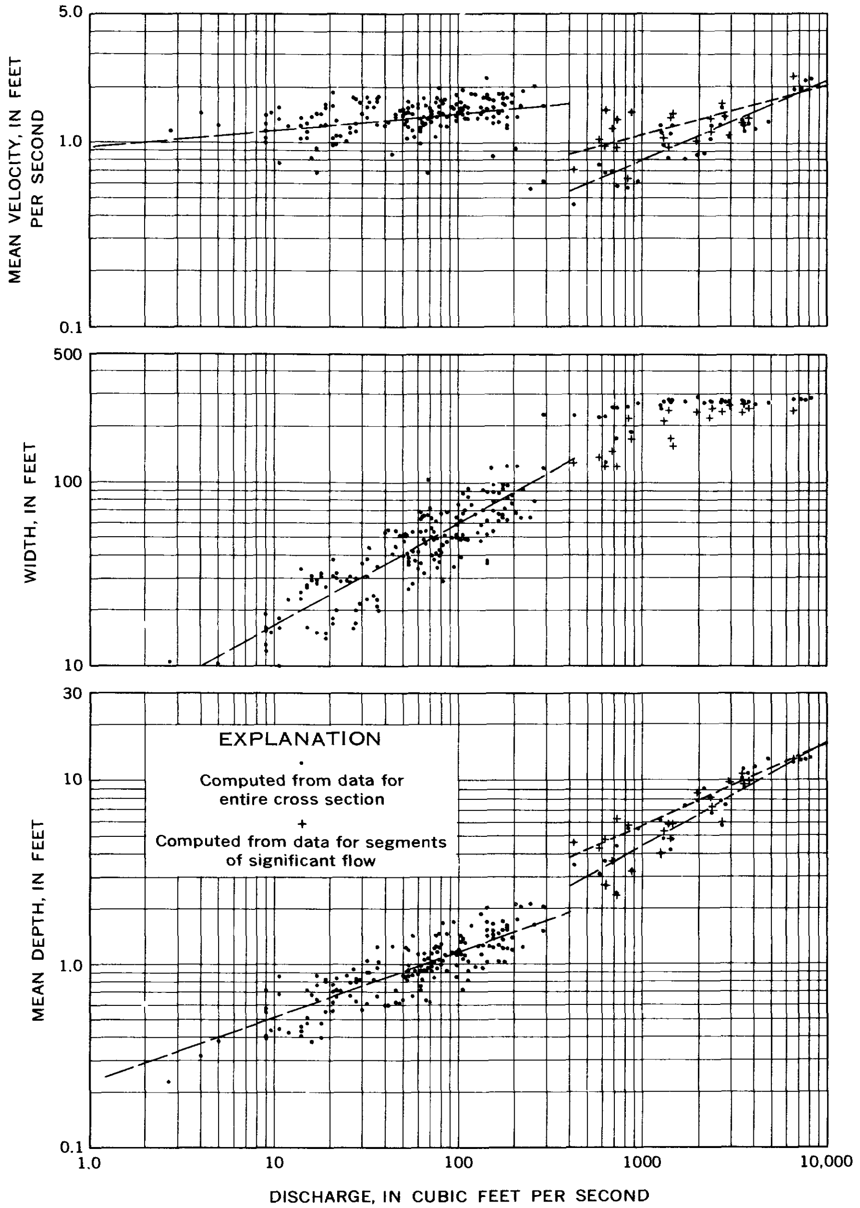

FIGURE 4.—Relations of width, mean depth, and mean velocity to water discharge, Little Arkansas River at Valley Center.

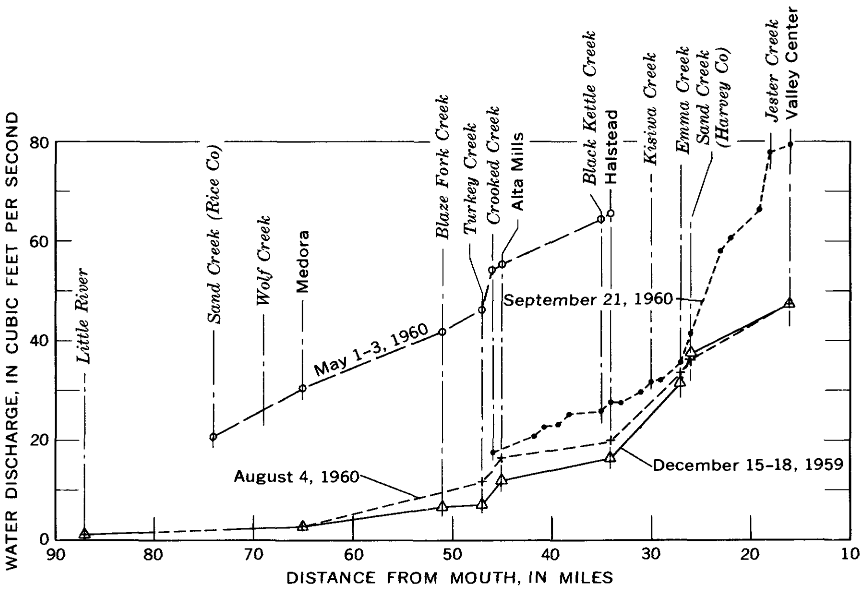

FIGURE 5.—Downstream increase in water discharge, Little Arkansas River, September 21, 1960. Measurements from seepage studies of various basins in Kansas by the Kansas Water Resources Board (unpub. data, 1960).

storage capacity of about 1,940 acre-feet. In the very small part of the basin in Reno County, no such reservoirs have been constructed, but there are several small natural lakes among the sand dunes. Many small natural lakes are also found in Harvey County.

FLUVIAL SEDIMENT

FIELD INVESTIGATIONS AND METHODS

The objectives of the investigation required the collection of comprehensive information on suspended-sediment concentration, suspended-sediment discharge, and particle-size distribution of suspended sediment and of bed material at the Little Arkansas River at Valley Center and at the floodway at Valley Center. Standard samplers and methods were used to obtain necessary field data.

In addition to the comprehensive investigations at Little Arkansas River at Valley Center, periodic investigations were made at many sites in the basin upstream from Valley Center. A three-sampler stack of automatic single-stage suspended-sediment samplers was installed at each of 22 of these sites; samples were thus obtained at predetermined gage heights during rising stages. Samples were obtained manually at the other sites during periods of significant runoff.

LABORATORY METHODS

Suspended-sediment concentration and particle-size distribution of suspended sediment and of bed material were determined by standard methods of the Geological Survey. Concentration was determined by either the evaporation method or the filtration-evaporation method. Particle-size analysis of suspended sediment was usually made by the pipet and visual-accumulation-tube method. The pipet was used for the silt-clay fraction, and the visual accumulation tube was used for the sand fraction. The suspension medium for silt-clay analysis was distilled water to which was added the chemically and mechanically dispersed sediment.

In a few samples, the silt-clay fraction was split; one part was analyzed dispersed and the other was analyzed in water from the stream. Because stream water may tend to flocculate the silt and clay particles, the analysis usually shows a much lower percentage of clay and fine silt than an analysis where the silt-clay fraction is dispersed. The results of such comparative analyses may give a rough indication of the behavior of the silt and clay under reservoir or stilling-basin conditions.

Bed-material samples were analyzed by sieve and visual accumulation tube. Fall diameters were determined by visual accumulation tube for the sand in the 0.062- to 1.0-millimeter range; particles larger than 1.0 mm were analyzed by the sieve. Usually less than 2 percent of the bed material was finer than 0.062 mm; therefore, the particle-size distribution of this fraction was not determined.

SUSPENDED SEDIMENT

The suspended-sediment load is fluvial sediment maintained in suspension by the upward components of turbulent currents or by colloidal suspension. Discharges of water and suspended sediment may vary widely in the basin during major runoff periods as a result of varying rainfall intensity and size of area covered. Suspended-sediment load varies only slightly during periods of normal or low flow and is derived mainly from alluvial material.

CONCENTRATION

During 1958–61, concentrations of suspended-sediment samples from Little Arkansas River at Valley Center ranged from about 10–4,200 parts per million; the maximum daily concentration was 2,960 ppm. The discharge-weighted mean concentration for 1958–61 was 882 ppm.

Daily concentrations were less than 100 ppm about 48 percent of the time (fig. 6) and less than 500 ppm about 82 percent of the time.

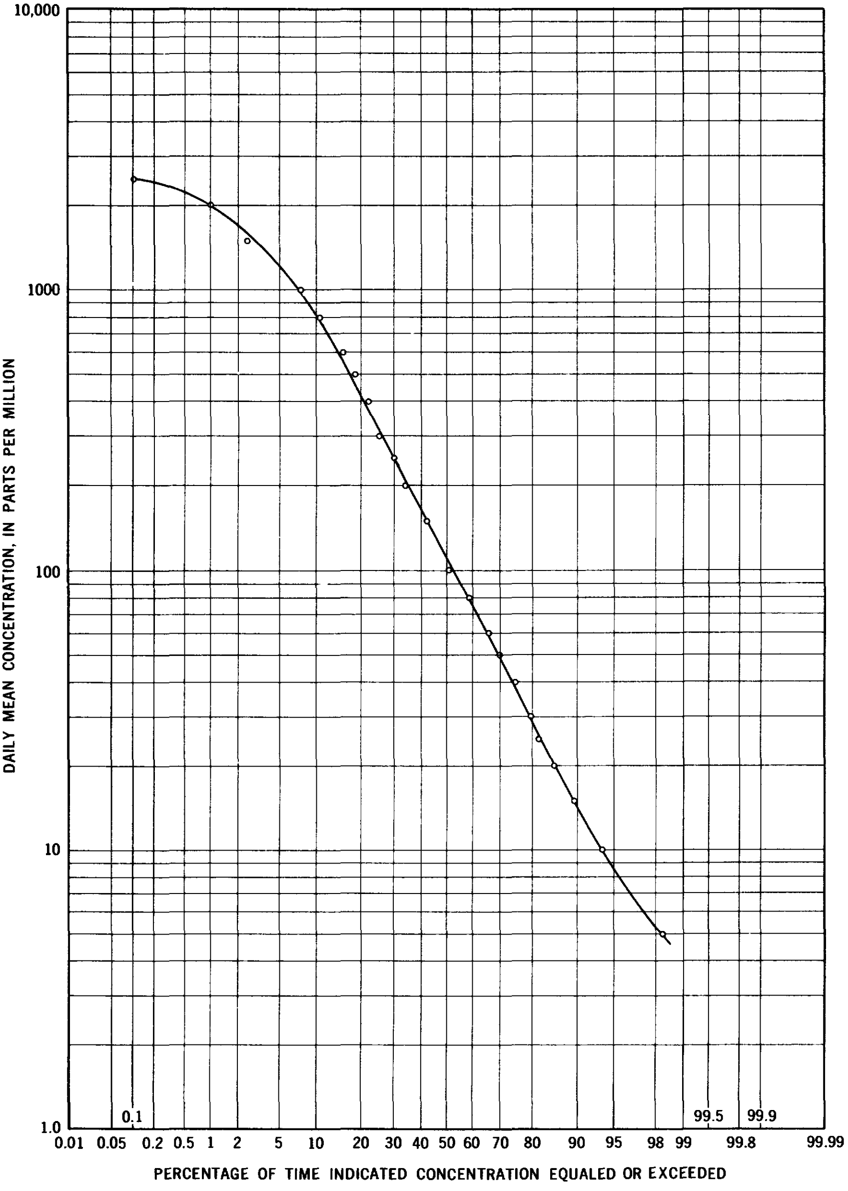

FIGURE 6.—Duration curve of daily mean concentration, Little Arkansas River at Valley Center. Based on data for 1959–61.

A partial-duration series was compiled for a period of 48 months, which is a relatively short period for such a series; this series was used in determining the expected recurrence intervals of average concentrations for periods of 12 hours, 24 hours, 3 days, and 7 days (fig. 7). The recurrence interval was computed from the formula $T=n+1/m$, where n is the number of months of record, and m is the order number of the average concentration for the indicated period, and 1 is the highest average concentration order. The recurrence interval is the average interval between occurrences without regard to seasonal variations; therefore, a given average concentration is likely to recur more often than average during the spring and summer months and less often than average during the fall and winter months. Because the period of record is short and the average annual discharge was higher than long-term average, the curves may not represent the long-term interval.

PARTICLE-SIZE DISTRIBUTION

Particle-size distribution of suspended sediment from the Little Arkansas River at Valley Center has little, if any, relation to water discharge, especially during periods when a significant part of the streamflow is contributed by overland flow. During such periods, the suspended sediment averaged about 85 percent of clay; about 75 percent of the sediment was less than 0.002 mm in diameter. Although the percentage of clay ranged from 72 to 97, most samples had a clay content within 4 percent of the average. In most samples, the percentage of sand was 2 or less. Current methods of particle-size analysis require chemical and mechanical dispersion of the sediment; the results, especially for the silt-and-clay range, represent sizes that would exist in the stream if certain chemical characteristics and hydraulic conditions existed. The analyses do not necessarily give results that represent the sizes of particles transported under streamflow conditions.

The particle-size distribution of suspended sediment during extended periods of base runoff was not well defined because collection of sufficient suspended sediment for size analyses is not practical during such periods. Because the concentrations and sediment discharges are very low during these periods, the lack of particle-size data is not an important deficiency.

SUSPENDED-SEDIMENT DISCHARGE

Standard methods were used to compute the daily and annual suspended-sediment discharge of the Little Arkansas River at Valley Center and of the floodway. The same methods were also used to compute instantaneous suspended-sediment discharge of many other

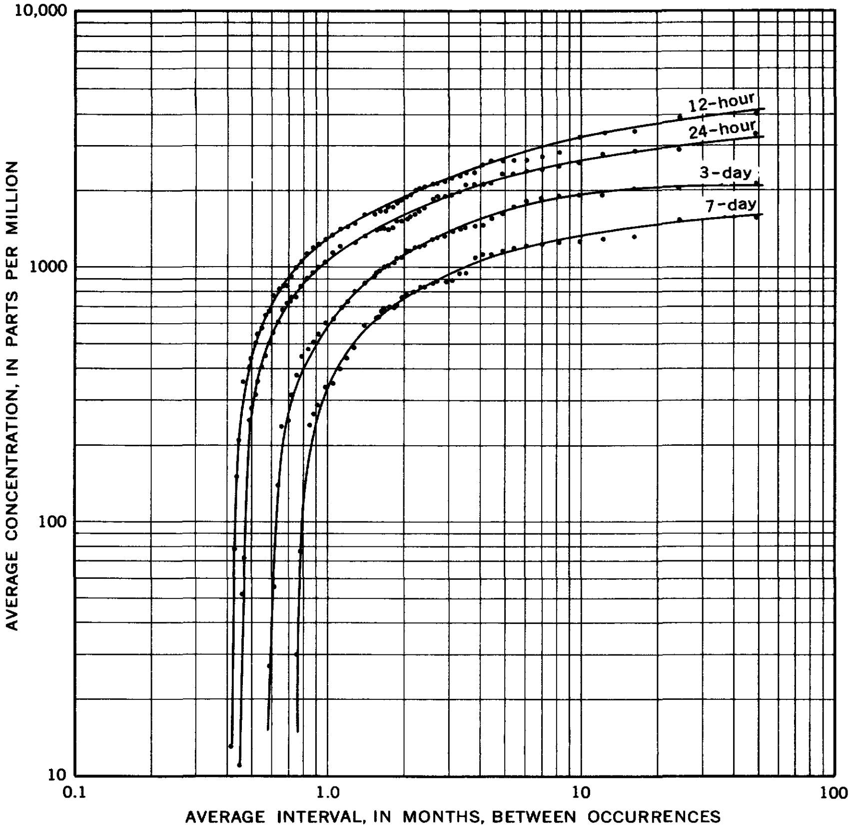

FIGURE 7.—Recurrence interval of average concentration of suspended sediment for indicated periods, Little Arkansas River. Based on data for 1958–61.

sites in the Little Arkansas River basin. The relation of annual suspended-sediment discharge to annual water discharge for the period 1958–61 is shown in figure 8. Much of the annual sediment discharge occurs during a small part of each year. During the 1958, 1959, 1960, and 1961 water years, about 80 percent of the sediment was transported during 37, 18, 48, and 30 days, respectively. The average annual suspended-sediment discharge was about 306,000 tons, which represents about 230 tons per year per square mile of drainage area. The Little Arkansas River, however, transports much of the total annual sediment load during a few days each year, and, in addition, a relatively small part of the basin probably contributes much of the total annual sediment load at Valley Center. Suspended-sediment yield, as indicated by data for Little Arkansas River at Valley Center, probably ranges from near zero in sand-dune areas to at least 1,000 tons per square mile in certain local areas.

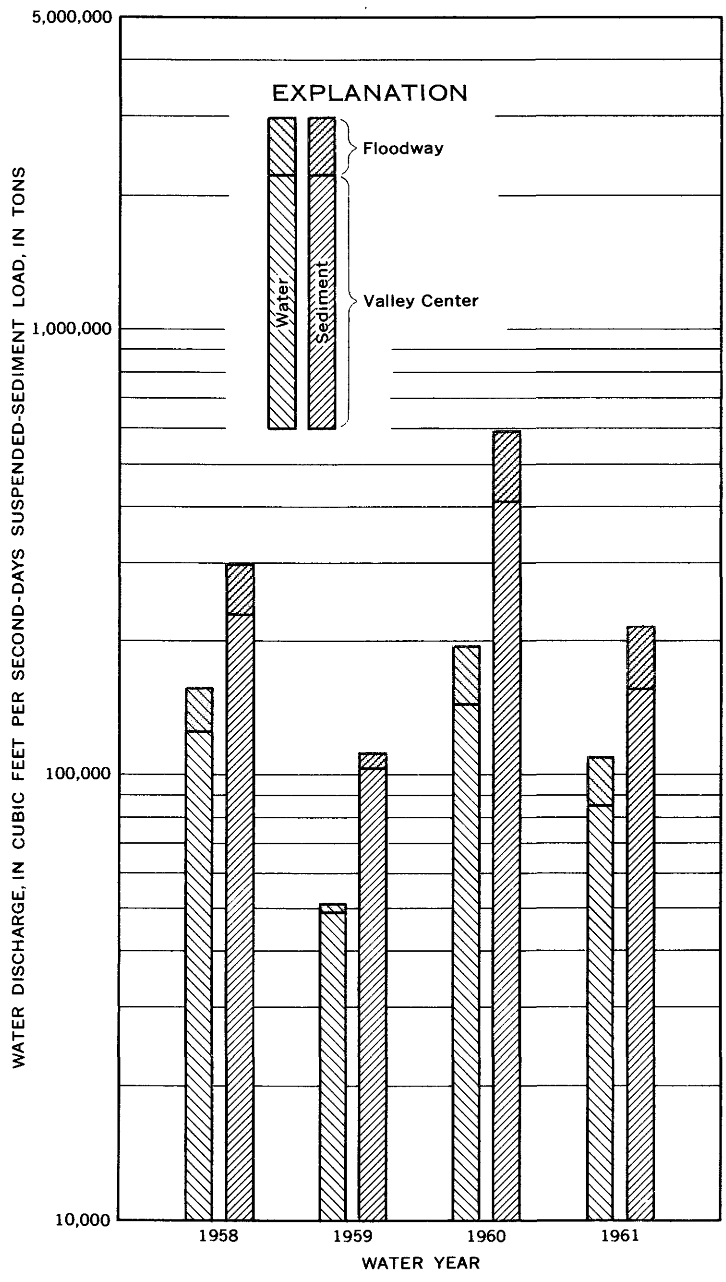

FIGURE 8.—Annual water discharge and annual suspended-sediment load, 1958–61, Little Arkansas River and floodway at Valley Center.

During 1958–61, the average daily water discharge was 352 cfs; the long-term average is 245 cfs. The average annual sediment load for the period 1958–61, therefore, is probably somewhat greater than would be expected for a long-term period.

The relation of sediment discharge to water discharge (fig. 9) shows that for discharges exceeding about 2,000 cfs, the relation for flow in the floodway is about the same as the relation for flow in the main channel. For flows less than about 2,000 cfs, however, the suspended-sediment load in the floodway would be much greater than that in the main channel at an equal water discharge. The concentration of suspended sediment in the floodway will be about equal to the concentration in the main channel because the suspended-sediment load is mostly clay, which will be fairly uniformly distributed both horizontally and vertically in the main channel. The floodway flow begins as the discharge reaches about 1,700 cfs in the main channel; the average concentration would be near 1,200 ppm, which would result in a load of about 30 tons per day at a discharge of 10 cfs in the floodway. The approximate floodway relation is sketched on figure 9 on the basis of computation and plotted points.

During the investigations, many suspended-sediment discharge measurements were made at Jacobs Bridge and at Fry Bridge upstream from the diversion dam. (See pl. 1.) For periods when flow occurred in both the main channel and the floodway, the computed sediment discharge at Jacobs Bridge or at Fry Bridge was about the same as the computed combined discharge of the Little Arkansas River at Valley Center and the floodway. The results of the investigation indicate no significant deposition in the floodway sill area.

On the basis of average particle-size distribution, suspended sediment of the Little Arkansas River would weigh about 50 pounds per cubic foot about 1 year after deposition. If the average annual load of 306,000 tons were deposited, the sediment would have a volume of about 280 acre-feet.

BED MATERIAL

Although the bed of the Little Arkansas River at Valley Center contains silt and coarse gravel, it is composed mainly of medium and very fine gravel. The bed material is principally quartz and was derived from Cretaceous, Pleistocene, and Recent deposits. Fifteen sets of bed-material samples were collected during 1958–61 at water discharges ranging from 29 to 3,140 cfs. Analytical results show considerable variation in particle-size distribution of the bed material, both from time to time at the section and from place to place across the section. The general relation of particle-size distribution to water discharge is shown in figure 10.

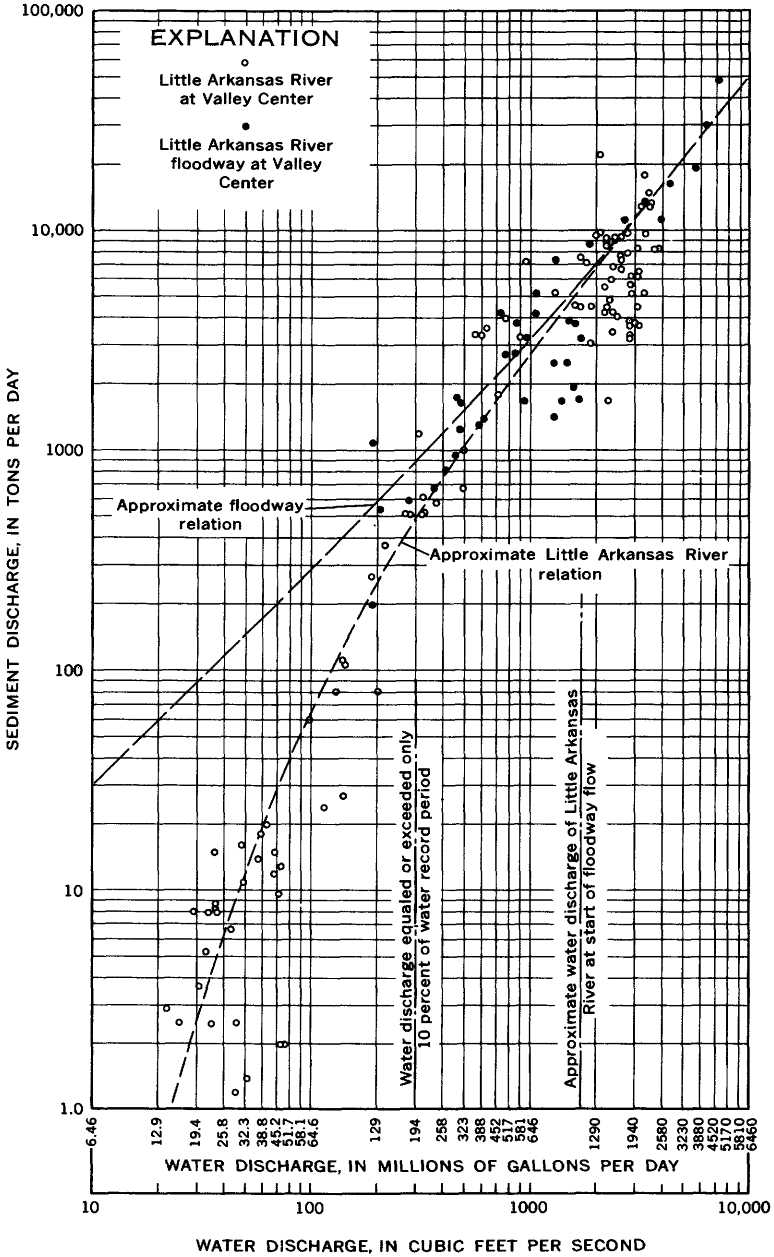

FIGURE 9.—Relation of water discharge to suspended-sediment discharge, Little Arkansas River and floodway at Valley Center.

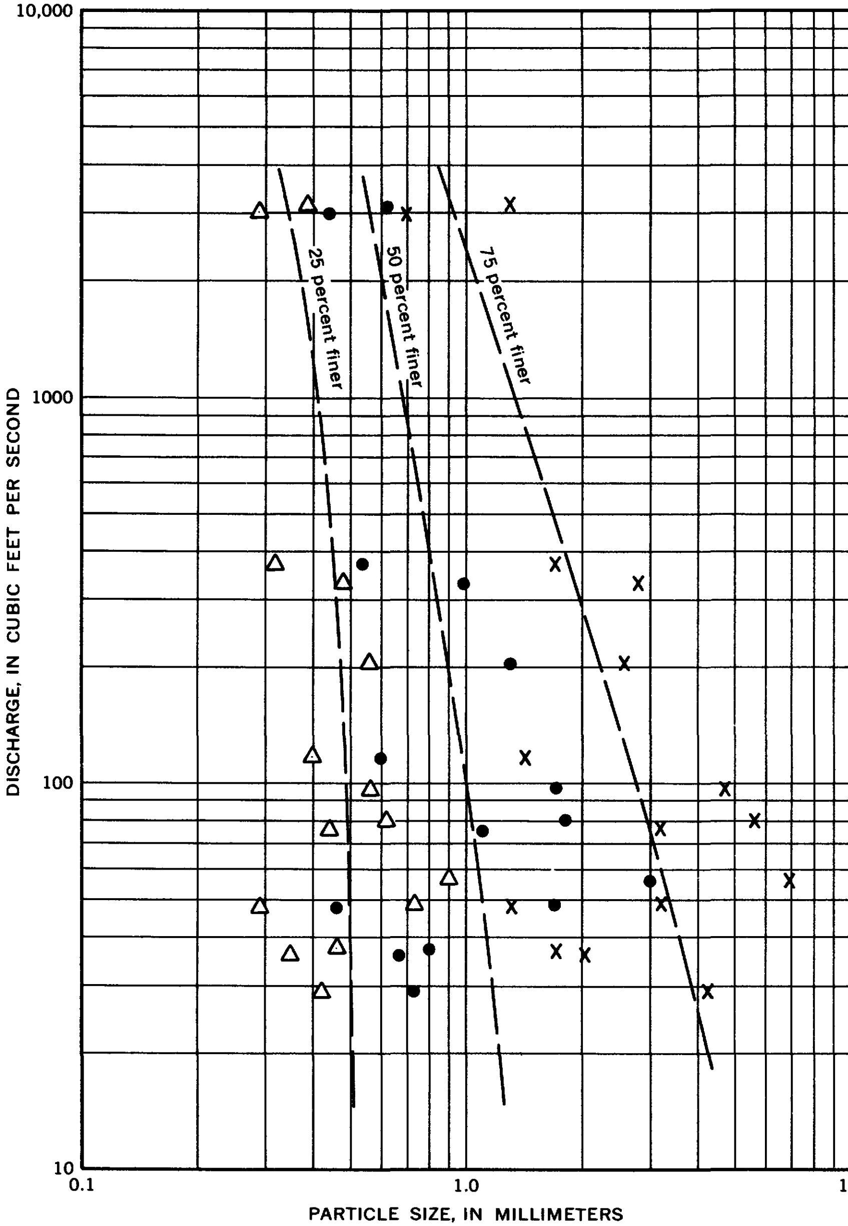

FIGURE 10.—Relation of particle size of bed material to water discharge, Little Arkansas River at Valley Center.

TOTAL SEDIMENT DISCHARGE

Movement of sand has been observed in shallow, clear-water sections on the Little Arkansas River. Sand grains were rolled along the bed by dune or sand-wave movement. Such movement contributes to the total sediment discharge of a stream, but measurement of this part of the total sediment discharge is not possible with currently available instruments. Computational methods for the approximation of total sediment discharge, however, have been advanced by Einstein (1950), Colby and Hubbell (1961), and others. These methods generally utilize data on streamflow, on particle size of bed material and of suspended sediment, and on water temperature. Colby (1957) developed a method for computing the "unmeasured sediment discharge"; this discharge added to the measured suspended-sediment discharge approximates the total sediment discharge of the stream. This method utilizes mean velocity, mean depth of flow, and suspended-sand concentration; unlike most other methods, this method does not require that one or more size ranges be present both in the bed material and in the suspended sediment. Because there is little or no overlap in size ranges of suspended sediment and bed material in the Little Arkansas River, the Colby method was used for computing the unmeasured loads for this stream. Computations of unmeasured sediment discharge were made for six sets of data. Figure 11 shows that total sediment discharge for Little Arkansas River at Valley Center is nearly all suspended-sediment load.

SOURCES OF SEDIMENT

The sediment transported by the Little Arkansas River is a composite of the materials contributed by the tributaries and the main stem. Some suspended-sediment data were obtained for many of the tributaries during periods when a significant part of the runoff was contributed by overland flow. The sediment concentration data and field observations suggest that Kisiwa Creek and Sand Creek (Rice County) probably have lower discharge-weighted suspended-sediment concentrations and sediment yields than the other tributaries and that Turkey, Black Kettle, and Emma Creeks have relatively high concentrations and sediment yields.

Sheet erosion probably contributes the largest percentage of the suspended-sediment load. Gully erosion is evident in the upper basin, but the amount of sediment contributed by such erosion is relatively minor. Streambank erosion probably contributes significant quantities of sediment during high stream stages, especially during extended periods of multiple rises when the banks are saturated and easily eroded.

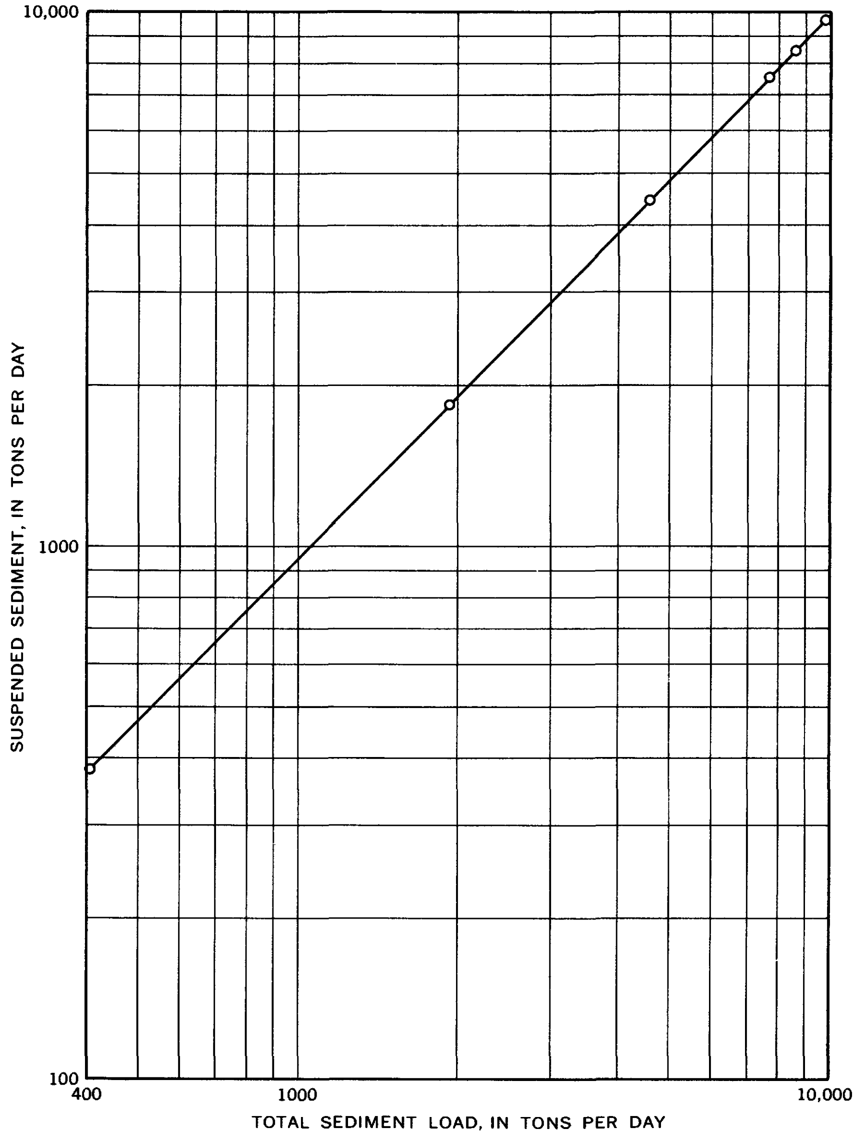

FIGURE 11.—Relation of total sediment load to suspended-sediment discharge, Little Arkansas River at Valley Center.

During the period August 1–5, 1958, high stages on the Arkansas River resulted in about 250 acre-feet of reverse flow through the Little Arkansas River floodway. A volumetric survey showed that the reverse flow eroded about 3 acre-feet of sediment from the sill area at the upstream end of the floodway. Much of this sediment was deposited in the area upstream from the floodway sill; some of it was transported down the main channel of the Little Arkansas River, and some was transported by the floodway when normal flow resumed.

SEEPAGE STUDIES OF KISIWA CREEK CHANNEL

Kisiwa Creek flows through the Wichita well-field area and empties into the Little Arkansas River a few miles upstream from Sedgwick. Because of a lack of well-defined drainage, the watershed retains much of the precipitation. Computations indicate that the ground-water recharge in the Wichita well-field area of Kisiwa Creek has averaged about 6 inches per year (Stramel, 1956).

Before 1940, according to local residents, Kisiwa Creek was a perennial stream in the lower reaches; since 1940, pumping in the Wichita well field has resulted in a decline in the water table in part of the watershed, and Kisiwa Creek is now an ephemeral stream. For about 10 miles upstream from its mouth, the bed of Kisiwa Creek lies above the water table. During the past 7 years, observed discharges of 1–4 million gallons per day (1.5–6.2 cfs) have seeped into the underlying gravel as the water flowed through the downstream reach of Kisiwa Creek in the eastern half of the well field. A thin, nearly impermeable layer of clay lies between the sands of the streambed and the top of the underlying sand and gravel in the western half of the Wichita well field; therefore, seepage from the channel is minor. Where the stream has cut through the clay and is in contact with the underlying sand and gravel, seepage readily occurs.

Studies by the Wichita Water Department in 1957 showed, tentatively, that an average of about 2 million gallons per day per mile (3.1 cfs per mi) seeped from the stream in the reach between the Wichita surface-water level recorder and the mouth of the stream (fig. 12). These studies were made prior to the excavation of a gravel pit immediately upstream from the study area. Appreciable quantities of fine sediment were washed from the gravels during the early stages of pit operation and were deposited as a thin layer on the streambed. Particle-size analyses showed that 93 percent of the suspended sediment in the water from gravel-pit operations was less than 0.002 mm in diameter. The fine-sediment deposit reduced seepage from the channel for at least 2 miles downstream from the pit.

During the gravel-pit operations, six seepage studies were made in a selected reach of Kisiwa Creek; results of the studies are shown in figure 13. In July the sediment from the gravel-pit operation was deposited on the streambed and thus reduced the rate of seepage from the channel. During the first part of October 1959, high discharges and appreciable bed scour occurred in Kisiwa Creek. By October 9, 1959, discharge had decreased to 6.7 cfs at section C and

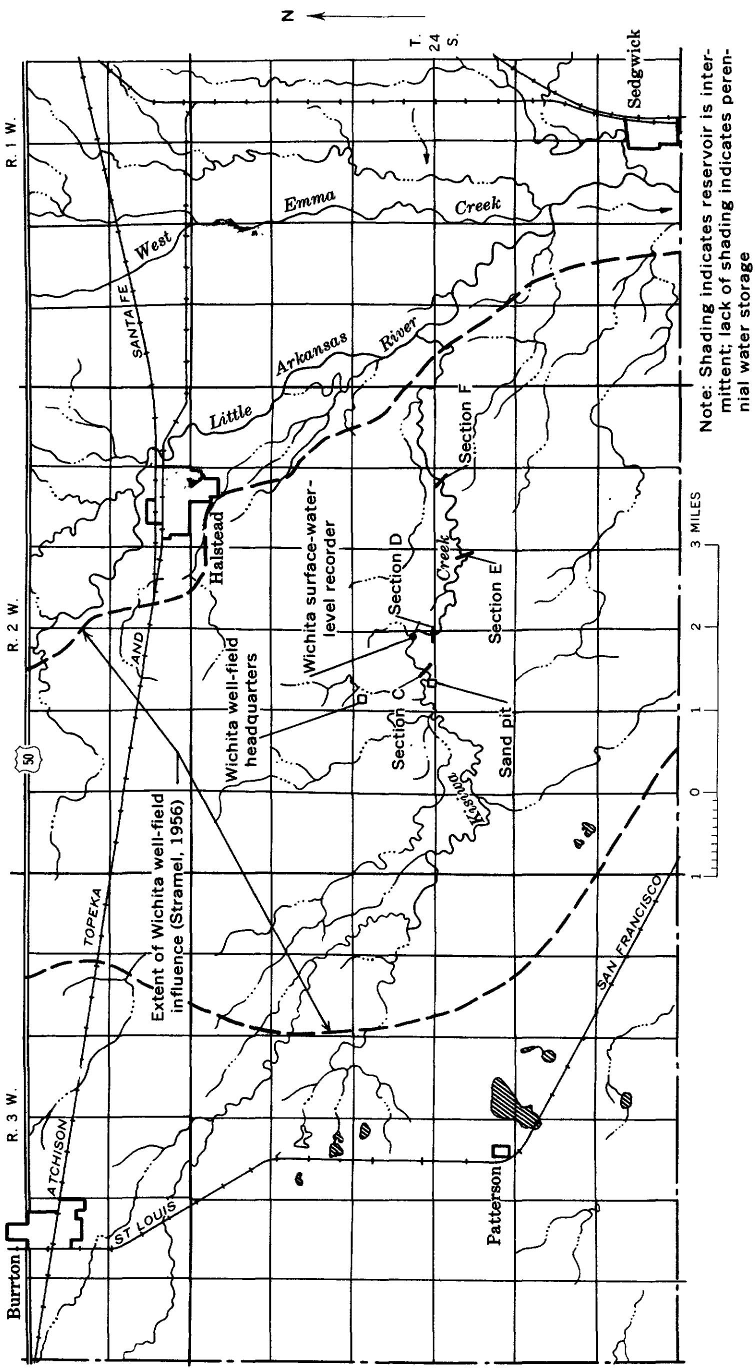

FIGURE 12.—Kisiwa Creek area.

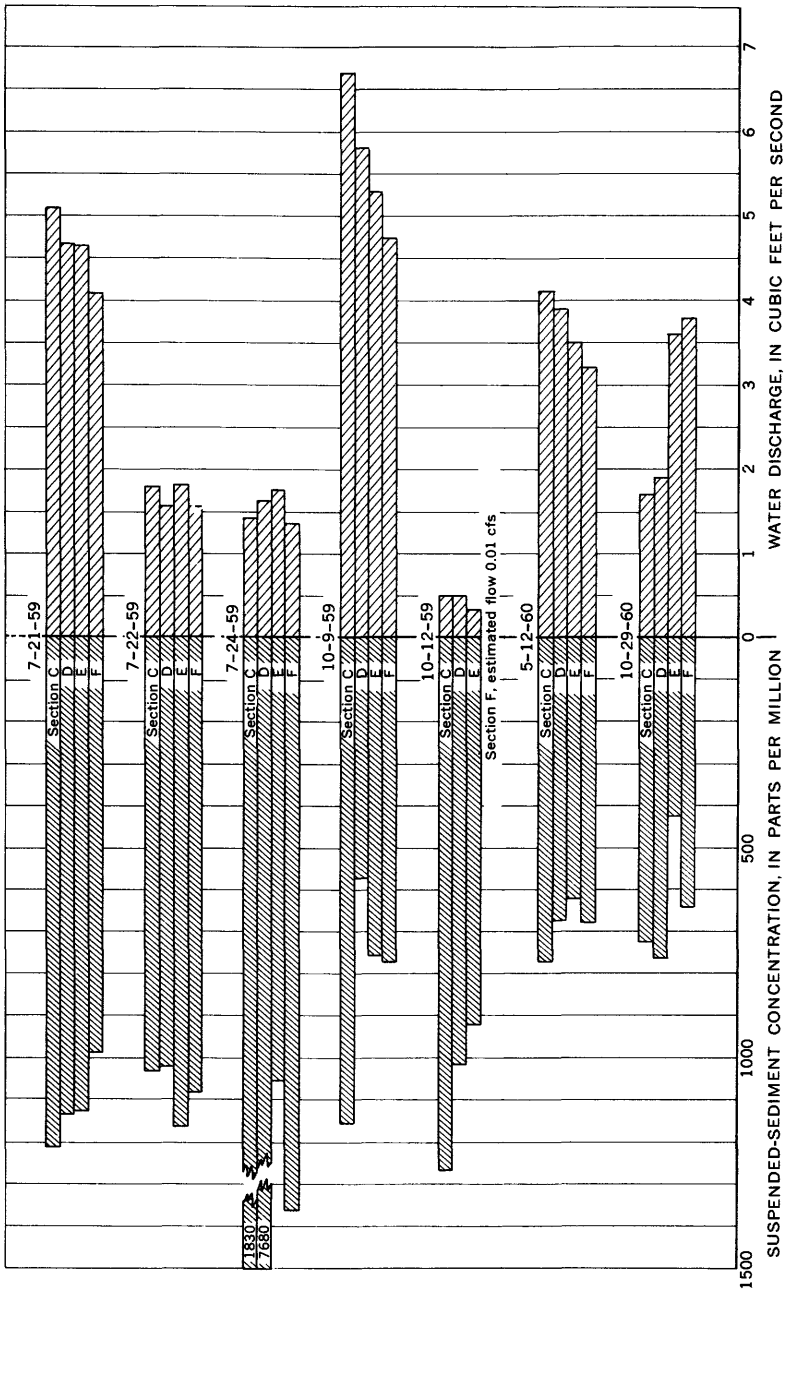

FIGURE 13.—Water discharge and suspended-sediment concentration, Kisiwa Creek near Halstead.

4.7 cfs at section F. (See fig. 13.) The decrease in discharge between sections C and F indicates that the scour effect of the high discharges increased the seepage from the channel.

Wash water from the gravel pit has been retained in the pit since late 1959, and no fine sediment has been deposited on the streambed since that time. During 1960 and 1961, seepage from Kisiwa Creek was equal to that observed prior to the gravel-pit operation. On October 29, 1960, however, which was immediately after an extended period of rainfall, a seepage study showed an increase in flow through the reach (fig. 13). The increase in flow was probably caused by seepage from temporary perched water bodies in small lenticular aquifers that crop out along the stream channel. During the time of increase in flow, seepage from the channel was probably appreciable, but inflow from perched zones exceeded seepage from the channel. A rate of 2 million gallons per day per mile still is considered to be an approximate value for seepage from the channel where the stream and the underlying aquifer are hydraulically continuous. High rates of ground-water recharge are indicated by water levels in observation wells adjacent to the creek and are apparent on water-table contour maps of the well-field area.

The relation between stream stage and water level in the underlying aquifer (fig. 14) shows that seepage from Kisiwa Creek varies with

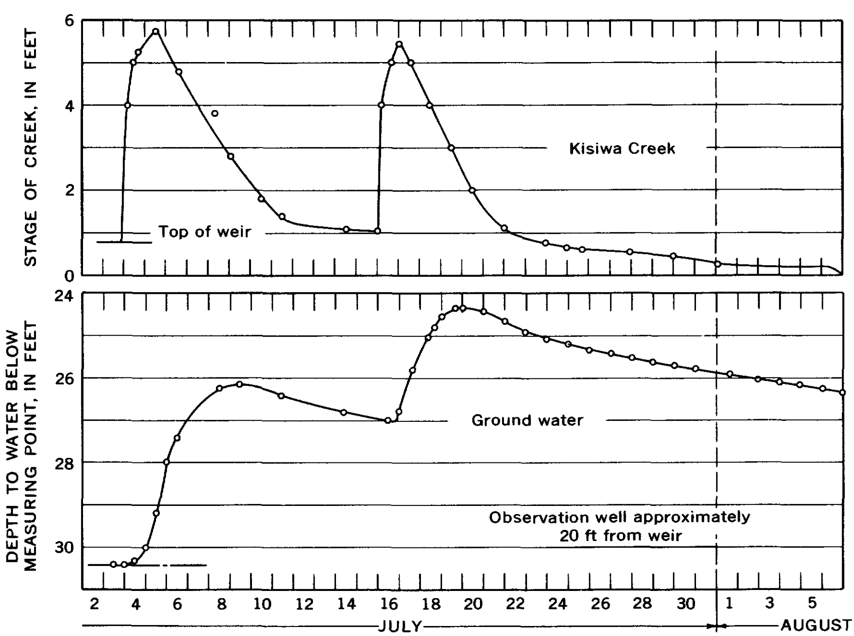

Figure 14.—Relation of surface-water stage to ground-water stage, July and August 1958, Kisiwa Creek.

stream stage. Increased seepage should be expected at high stream stages because of the increased hydraulic head and because of the larger area covered by flow. Also, local scour during high discharges probably increases the permeability of the streambed.

GROUND-WATER RECHARGE STUDIES

Studies by the Wichita Water Department during 1958–61 indicate that artificial recharge using raw turbid water for injection into wells and pits is probably not feasible. From these studies the Water Department has tentatively concluded that raw turbid water must have the suspended solids removed before injection into wells or pits. The clay particles in the surface water that was used for injection plugged the recharge wells and the recharge pit after short recharge runs.

Recharge with raw turbid water during low- to medium-flow periods may be feasible if large permeable areas are available. Recharge by means of seepage canals, similar to natural recharge in the lower reaches of Kisiwa Creek, may also be feasible.

CHEMICAL QUALITY OF SURFACE WATER

Studies were made of the chemical quality of surface water at several sites in the Little Arkansas River basin. These studies were designed to supplement periodic data collected by the Wichita Water Department, to provide some information on chemical quality of water as the suspended-sediment transport medium, and to determine the probable range of dissolved solids.

The dissolved-solids and chloride concentrations of water in Turkey Creek varied greatly from time to time, although water discharge varied only slightly. The data show that chloride was 8–56 percent of the dissolved-solids load; in general, chloride content of the water increased as the total dissolved-solids content increased. Chloride concentrations were generally less than 1,000 ppm; the maximum observed concentration was 1,600 ppm, and the minimum was 21 ppm. Generally, chloride and dissolved solids varied inversely with water discharge and suspended-sediment concentrations.

The results of a low-flow chloride survey of the Little Arkansas River in December 1959, when suspended-sediment concentrations were low, show that the chloride concentration increased from 48 ppm north of Little River to a maximum of 324 ppm at Alta Mills and then decreased to 144 ppm at Valley Center. The increase at Alta Mills was caused by inflow from Turkey Creek, which had a chloride concentration of 710 ppm. The inflow was nearly half of the Little Arkansas River flow at this point. The chloride load, in tons per day, increased from about 0.1 north of Little River to about 10 at Alta Mills and to about 18 at Valley Center. Turkey Creek contributed about 9 tons per day, or about half the load at Valley Center. The results of this survey are representative only of flow conditions at the time of the survey.

The interpretation of periodic sample results from the Wichita Water Department is beyond the scope of this report. Results of comparative samples from Turkey Creek and Sand Creek (Rice County), however, show that Sand Creek contained more chloride; concentrations were as high as 5,000 ppm in Sand Creek. Tonnages of chloride were not determined. A current trend of slight decrease in chloride concentrations for both Sand and Turkey Creeks may be significant to future water use.

SUMMARY

Concentrations of suspended-sediment samples ranged from about 10–4,200 ppm, and daily mean concentrations ranged from less than 10–2,960 ppm. Daily mean concentrations for the period of study were less than 550 ppm about 82 percent of the time and less than 100 ppm about 48 percent of the time. Periods when daily concentrations are 100 ppm or greater recur about twice a month on the average. Suspended sediment taken in periods when a significant part of the streamflow was contributed by overland flow averaged about 85 percent clay, 13 percent silt and 2 percent or less sand.

The average annual suspended-sediment discharge was about 306,000 tons, and the average daily water discharge was 352 cfs during 1958–61. The long-term average daily water discharge is 245 cfs; therefore, the average annual sediment load for 1958–61 is probably somewhat higher than would be expected for a long-term period.

Results of sediment investigations show that, although sediment concentrations and loads may have wide variance, the suitability of water for direct municipal use is adequate most of the time; however, available treatment facilities might dictate selective use during periods of high sediment concentrations.

Studies of seepage in a part of the channel of Kisiwa Creek showed that generally seepage occurred at a rate of 2 million gallons per day per mile during periods of flow. This rate was temporarily affected by clays from gravel-pit wash water. The modification of gravel-pit operation and subsequent runoff that scoured the channel reestablished seepage rates.

Low-flow studies of chemical quality of surface waters in the Little Arkansas River basin show that the chloride load, in tons per day, increased from about 0.1 north of Little River to about 10 at Alta Mills

and to about 18 at Valley Center. Turkey Creek contributed about 9 tons per day or about half the load at Valley Center. The results of the survey are representative only of flow conditions at the time of the survey. Results of periodic samples collected by the Wichita Water Department show Sand Creek (Rice County) as a contributor of high chloride concentrations during periods of flow, but concentrations at all sampled locations are generally decreasing with time.

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